Promoting Independent Mobility

-Assistance mobility and evaluation technology in robotic wheelchair-

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***Abstract*— A rapid population increase of elderly people has caused several issues including the need for eco-friendly and comfortable mobility. In this paper, on-going projects related to mobility technology for elderly people are discussed. We propose robotic autonomous wheelchairs to aid in resolving mobility problems for the elderly. When using an autonomous wheelchair, the rider does not need to control the wheelchair. However, there are several challenges associated with the use of an autonomous system. One of the most difficult challenges to overcome is the purchase price. Normally, an autonomous wheelchair is costly because of several expensive sensors that are required for full autonomous functionality. Thus, it is difficult for elderly people to own an autonomous wheelchair.**

We introduce three projects including an assistance cart, and two other projects related to autonomous wheelchairs. The cart supports elderly people during walking and enables travel for greater distances without full autonomous features. The autonomous robotic wheelchairs have GPS, laser scanner sensors (LIDAR), and gyro sensors. We are researching positioning techniques, obstacle avoidance methods, rider usability, and a human machine interface to further expand the usage of autonomous wheelchairs. In addition, experimental results on usability and gesture recognition interface are discussed in this paper.

I. Introduction

In Japan, a greater proportion of elderly people (over 65 years old) are involved in road fatalities than people of any other age group, as shown in Fig. 1 [1]. Because of the advancement of science and inherent adaptability of humankind to changing life conditions, average life expectancy has increased. This leads to an increasing population of aged and disabled people in need of mobility aid. Current figures indicate that nearly 15% of the population, which corresponds to approximately one billion in the world, has some form of physical disability or impairment [2]. Additionally, according to studies [3, 4] the household rate of people in the US using wheelchairs doubled from 1.5% to 3% from 1990 to 2010 with a majority of these being elderly people. Automobiles are the optimal means of transportation for the elderly since automobiles permit door-to-door transportation [5, 6]. However, to address traffic problems related to air pollution in city areas, a shift in use from individual automobiles to public transportation is needed. This change will be less than ideal for elderly people. To resolve this conflict, useful and eco-friendly transportation must be provided. Public transportation is useful and eco-friendly; however, the last-mile problem remains, especially for elderly people [7, 8]. Convenient, comfortable, and eco-friendly mobility is considered one of the options for solving this problem of the last mile.

We proposed robotic autonomous wheelchairs to solve mobility issues. With an autonomous wheelchair, the rider is not required to control the chair. However, there are several challenges associated with the use of an autonomous system, the most difficult being cost. Several expensive sensors are necessary for a wheelchair to achieve complete autonomous functionality. These sensors increase the cost of an autonomous wheelchair, making it difficult for elderly people to purchase an autonomous wheelchair. We introduce three projects in this paper regarding autonomous or assisted wheelchairs and how they will aid the elderly.

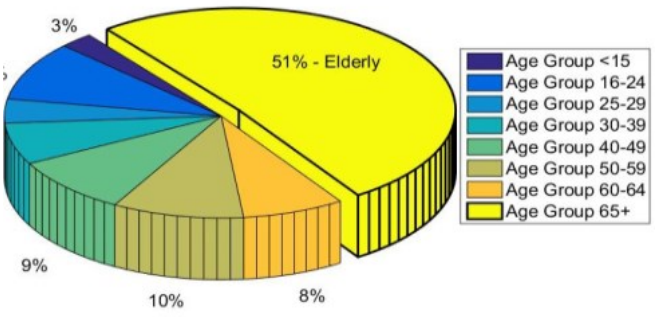

Figure 1. Number of traffic accident fatalities by age group [1]

II. Assistant Mobility Device

In the automobile field, there are numerous on-going research projects regarding automated vehicles for use on public roads; however, there are still challenging issues such as the overall cost that require resolution [9-12]. While the cost of autonomous functionality within an automobile is relatively small compared to the cost of a vehicle, the overall high cost of an autonomous vehicle can be a serious problem for the elderly. National Institute of Advanced Industrial Science and Technology (AIST) is studying not only options

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for autonomous mobility but also assistance mobility for elderly people. This paper explains three assistance levels of mobility devices for elderly people.

A. Autonomous Robotic Wheelchair

Autonomous wheelchairs for assisting elderly and disabled people are proposed to assist in their daily activities [13-15] and are shown in Fig. 2. These wheelchairs can seamlessly travel in both indoor and outdoor environments through self-positioning and route planning. A localization method determines the wheelchair's own position using a 3D laser range scanner sensor attached to the wheelchair in conjunction with 3D maps. To avoid collisions, the system uses short-term and long-term planning methods. The short-term method, which is used within obstacle sensor area, finds a safe travel pattern through map simulations of every conceivable pattern. The long-term method generates a feasible route to the desired destination. If the route generated by the long-term method presents obstacle or collision hazards, the wheelchair uses the short term planning to avoid the hazard. The localization and the planning systems enabled our wheelchair to travel in public spaces autonomously. We are now researching methods to reduce the cost of this autonomous wheelchair system.

Figure 2. Two Robotic Wheelchairs

B. Experiment of Human Factors on Robotic Wheelchair

It is difficult to develop a completely autonomous wheelchair that functions in public areas. Multiple users of public space, including pedestrians and bicycles, create a challenging environment for an autonomous wheelchair. Therefore, it is necessary to include surveillance equipment for emergency or any robot unstable conditions into the design of mobile autonomous systems. Experimental studies of surveillance equipment, using real life conditions, are required to provide accurate data.

We studied human factors regarding the acceptability and capability of surveillance equipment, including the age of the user and duration of use. We created experimental scenarios to test the wheelchair in public areas, as shown in Fig. 3, to estimate a user's surveillance capability. The experimental results indicated differences in each ride.

Figure 3. Experimental scenes

C. Proposed Interfaces of Gesture Recognition for Robotic Wheelchair

A joystick is typically used as an interface for control of a wheelchair. The joystick controller is useful and simple to operate. However, the normal joystick has only four types of inputs. Additionally, some elderly people have challenges using a standard joystick. Alternatively, there are new interface tools available in the marketplace [16-18]. These smart interfaces pave the way for Human Machine Interfaces that aim to decrease the physical and cognitive loads of the users. The smart systems, however, are difficult to use for those who are handicapped or have some form of physical disabilities. This study is the first step toward developing a wheelchair control interface that will allow people having severe mobility impairments to use gestures and postures to control a wheelchair. This method of control is accomplished by using state of the art sensors, such as a pressure distribution sensor or the gesture armband from Microsoft.

A gesture and posture recognition algorithm was proposed for a robotic wheelchair as a replacement for a conventional joystick control [19]. For our experiments, we employed a Leap Motion sensor to capture the positions of the left hand, as shown in Fig. 4. The Leap Motion sensor reports the palm position, hand velocity, and orientation values at sub-millimeter accuracies.

A critical issue in recognizing real time signal patterns of the user's hand motion is the determination of the signal patterns without definite starting and stopping points. The problem of finding the most representative signal patterns was solved by employing subspace clustering methods. The use of subspace clustering, including the necessary algorithms, constitutes the framework used for different classification tasks. Further, we also implemented spectral variants of the Collaborative Representation based Classification as presented with MYO arm band [20, 21], shown in Fig.5

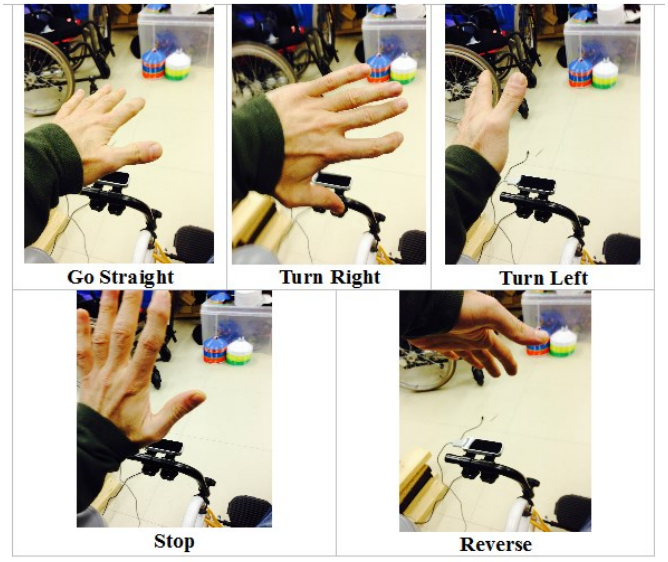

Figure 4. Hand gestures using Leap Motion: 1-Go Straight; 2-Turn Right; 3-Turn Left; 4-Stop; 5-Reverse

Figure 5. MYO armband and hand gestures, 1-Fist, 2-Hand relax, 3-Fingers spread, 4-Wave in, 5-Wave out, 6-Double tap conclusion

D. Robotic Assist Walker

The Ministry of Economy Trade and Industry organized the Development and Introduction of Robotic Devices for Nursing Care [22]. The objectives of the project are as follows [22]:

- To perform research and development into the introduction and promotion of robotic devices for nursing care facilities, thereby contributing to the independence of elderly people,
- To formulate and evaluate standards that are necessary to commercialize robotic devices for nursing care facilities,
- To provide financial support to enterprises that develop robotic devices for nursing care that fulfill criteria categorized in the government's "Priority Areas to Which Robot Technology is to be Introduced in Nursing Care of the Elderly".

Through this project, the Walking Assist Cart has been produced by The RT. WORKS Co., LTD., as shown in Fig. 6 [23]. The cart has an assistance function; however, it does not function autonomously. The objective of this cart is to provide support for elderly people and enable them to travel greater distances. It is a simple and low-maintenance cart that provides features developed for elderly people. Experiments were performed with elderly people, which provided feedback to improve the design of the cart. The cart is not an expensive system and has an effective technology to address mobility concerns of elderly people.

Figure 6. Walking Assist Cart

III. SUMMARY

This paper introduces mobility devices being developed at AIST and manufactured by a private company. The concept, system configuration, and experimental summaries are explained in this report. As the number of elderly people increase, personal mobility devices, including wheelchairs, become necessary for maintaining a high quality of life.

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